

BOULDER DAM-SAN BERNARDINO (115K V) TRANSMISSION
LINE
Eldorado to Ivanpah Section
Primm vicinity
Clark County
Nevada

HAER NV-45
HAER NV-45

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

FIELD RECORDS

HISTORIC AMERICAN ENGINEERING RECORD
PACIFIC WEST REGIONAL OFFICE
National Park Service
U.S. Department of the Interior
1111 Jackson Street, Suite 700
Oakland, CA 94607

HISTORIC AMERICAN ENGINEERING RECORD

Boulder Dam-San Bernardino (115kV) Transmission Line HAER No. NV-45

Location: The section of transmission line documented in this HAER report begins near the proposed Ivanpah Substation in the Ivanpah Valley area of San Bernardino County, California and runs for approximately 35 miles northeast to the Eldorado Substation in the Eldorado Valley of Clark County, south of Boulder City, Nevada.

UTM Location/References:

Zone 11 639150 E _3934543 N; **Zone** 11 652608 E 3951802; **N Zone** 11 679991 E 3963661 N

Present

Owner: Southern California Edison Company
2244 Walnut Grove Avenue, P.O. Box 800, Rosemead, CA.

Present Use: Transmission of electric power.

Significance: The Boulder Dam-San Bernardino Transmission Line (SBR-CA-10315H) was built in 1930-31 from San Bernardino, California to the Boulder Dam (later named Hoover Dam) site on the Colorado River to supply power for dam construction. After electrical generation began at the dam in 1937, the flow of electrical current was reversed to provide power to markets in Southern California. Completed on June 25, 1931, the transmission line was the first to be constructed to provide electricity for the initial construction phases of both Hoover Dam and Boulder City. It has been determined eligible for the National Register of Historic Places (NRHP) for its place in American history as an integral part of the success of the construction of the Boulder Dam and as a rare example of low-voltage long distance electrical transmission (Letter from Henri R. Bisson/BLM to Steade Craig/OHP, 14 October 1993).

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Project

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Project sponsored by Southern California Edison Company, Biological & Archaeological Resources Group (Koral Ahmet, Project lead), Corporate Environment, Health & Safety Division, 2244 Walnut Grove Ave., Rosemead, CA.

INTRODUCTION

Southern California Edison (SCE), in cooperation with the Bureau of Land Management (BLM), is planning to replace a section of existing SCE 115kV electrical transmission line with a 35-mile double-circuit 220kV transmission line. The section of line scheduled for replacement begins in the Ivanpah Valley area in Southern California and travels approximately thirty-five miles northeast to the Eldorado Substation, south of Boulder City, Nevada. The Boulder-San Bernardino Electrical Transmission Line (CA-SBR-10315H) as a whole is comprised of approximately 225 miles of transmission line that stretches from the San Bernardino Substation in San Bernardino County, California to the Eldorado Substation in Clark County, Nevada.

The California State Historic Preservation Officer concurred on October 21, 1993 with the BLM assessment of the Boulder Dam-San Bernardino Transmission Line as eligible for listing on the National Register of Historic Places. In compliance with regulatory directive, this Historic American Engineering Record (HAER) report is submitted as partial mitigation for the adverse effect of replacement of this 35-mile section of the line.

PHYSICAL HISTORY

Date of Construction: 1930-1931

Engineers: R. H. Halpenny (Electrical Engineer); E. J. Waugh (Construction Engineer) – Southern Sierras Power Company

Builder: C. H. Rhudy (Transmission Line Construction Supervisor); H. O. Watts (Boulder Dam Substation Construction Supervisor) - Southern Sierras Power Company

With the understanding that large quantities of power would be required for the construction of Hoover Dam, the U.S. Bureau of Reclamation chose to import electricity rather than to construct a generating plant at the dam site. As a result, a contract was awarded jointly to the Southern Sierras Power Company and the Nevada-California Power Company for the construction of a 225-mile transmission line from San Bernardino, CA to the dam site. The contract also included the construction of a substation near the rim of the canyon. Built in 1930-31, the transmission line and substation provided the power required for the construction of the Hoover Dam; it also provided domestic service to Boulder City.

The most common tower used in the construction of this transmission line was a 52-foot, H-frame steel structure consisting of two lattice masts, each 2 feet square in section and spaced 17 feet apart, which support a 34 foot long horizontal, trussed channel cross-arm (Type "H" Standard Tower). At least one of these towers in every mile of tangent (straight-line) run was guyed.¹ Self-supporting A-frame towers (Type "AL" Towers) were used for line angles between 25 and 50 degrees. For angles over 50 degrees, an Angle Structure (Type "AP" Tower) consisting of three vertical, guyed masts joined at the top by a horizontal arm of the same design, were used. Lattice steel H-frame Transposition Towers (Type "T" Towers), 64

¹ A guyed mast is a mast or tower is one that receives support from guy lines or wires. A guy wire is a tensioned cable designed to add stability to structures. One end of the cable is attached to the structure, and the other is anchored to the ground at a distance from the structure's base. They are often configured radially (equally spaced about the structure) in trios, quads (pairs of pairs) or other sets. This allows the tension of each guy wire to offset that of the others.

feet in height, were used to change the relative positions of the three conductors. This was done to prevent the buildup of inductive currents and attendant electromotive forces that interfered with radio signals and nearby communications-line transmissions. The transmission line was additionally provided with Sectionalizing Switch Towers (Type "SW" Towers) for opening the line at six points in the 225 miles of length.²

Tower bases, which are comprised of a steel cage structure, were set into the ground by means of earth boring machines and, in some cases, air driven tools where it was necessary to drill into solid rock. The towers were then individually constructed on site, using the prefabricated steel components. After the construction crew completed the tower structure, it was ready for the line stringing and guying crews. In order to lay out the conductor at the base of the towers, the stringing crew mounted three cable reels, each containing 4,000 feet of cable, onto three specially designed trailers. These individually drawn reel carriers made it possible to distribute the cable over rough terrain. When a cable spool ran out, line conductor was spliced together by means of two, 24" aluminum sleeves, through which the ends of the cable were inserted and twisted together.³

Spaced 750 feet apart on average, the towers carried a single circuit consisting of three aluminum cable steel reinforced (ASCR) conductors, each made up of six strands of aluminum wrapped around a steel core, with an outside diameter of about 5/8 inch. Insulators generally consisted of nine units strung together where the conductor was suspended, and ten units where the conductor was dead-ended. Originally, the Hoover Dam substation was the only switching station for the power line in Nevada. Other original intermediate substations were located at Victorville, Daggett and Barstow. The line was designed to carry power at 138kV both to Hoover Dam during construction and from Hoover Dam to San Bernardino and intermediate points following completion of the dam and powerhouses.⁴

A telephone line for transmission-line communications was constructed at the same time; however, with the exception of a remnant section of five deteriorated single wood poles in the vicinity of the McCullough range in Nevada, this telephone line is no longer extant. The Interstate Telegraph Company operated two automated ("dial") telephone circuits which crossed the San Bernardino Mountains north to Victorville and Barstow, and then ran east as far as Yermo, about ten miles from Barstow. The power company built a new, 140-mile telephone line from Yermo to Boulder City and routed it roughly parallel to the transmission line so that access roads could service both; the transmission line and telephone line were separated by about a half mile to prevent inductive interference in the telephone line by the transmission line. The telephone line was of No. 10 N.B.S. copper wire on 25-foot, treated cedar poles, using bracket (cross-arm) construction.⁵

² Dames & Moore. "Class III Cultural Resource Inventory for Los Angeles Department of Water and Power – Mead to Adelanto Transmission Line Project: Cronese and Calico Divisions." (Prepared for the City of Los Angeles Department of Water and Power, March 1995), 118. Also, "Nevada-California Electric Corporation – Hoover Dam Line Construction, 1930-31," (documentary album). Southern California Edison Collection (Collection 13, Volume 152), Huntington Library, San Marino, CA.

³ "Nevada-California Electric Corporation – Hoover Dam Line Construction, 1930-31," (documentary album).

⁴ Dames & Moore, 118. Also, Jay K. Sander and Jessica J. Auck. Nevada State Historic Preservation Office, Historic Resource Inventory Form (HRIF) for the "Class III Cultural Resource Inventory for Southern California Edison Eldorado-Ivanpah Transmission Project, San Bernardino County, California and Clark County, Nevada." (Redlands: CA: The Chambers Group, Inc., 2008), 8.

⁵ Dames & Moore, 118. Also, Blair, 30.

The standard insulator type found on the transmission line is a porcelain disk with a distinctive light blue glaze and an integral metal connector on either side. Stamped in black on the back of each insulator is the following: 'HI, Mfg. J-D, Jan. 1931, Pat. Nos. 1,329,770 & 1,716,963.' The designation "J-D" is short for the Jeffery Dewitt Insulator Company, manufacturer of the transmission line insulators. In 1908, Dr. Joseph A. Jeffery, his brother Benjamin A. Jeffery, and Benjamin's brother-in-law, Mortimer C. Dewitt started the Jeffery-Dewitt Co. in Newark, New Jersey to make spark plugs. The company also produced porcelain for sanitary ware, insulators, tumbling jars, crucibles, and other items. In February 1910, they moved the manufacturing headquarters to Detroit, MI, and in January 1916, Robert M. Johnston, a Detroit-based engineer, filed for a patent for a thick porcelain suspension insulator and assigned the Jeffery-Dewitt Co. as the manufacturer. The patent was not granted until February 1920 (1,329,770). Johnston filed a secondary patent on March 29, 1920 for an upgraded design of the original insulator type; this patent was granted in June 1929 (1,716,963). The insulator was designed specifically for long distance power transmission.⁶

Alterations and Additions:

As originally built, the only substation constructed for the power line in Nevada was located at Hoover Dam. Later Nevada substations, located at McCullough, Eldorado, Mead, Boulder City and Market Place were built after 1960. The original California substations were located at Victorville, Daggett and Barstow.⁷ SCE records indicate that these were replaced in 1950, after Southern California Edison took over operation of the line from Southern Sierras Power Company.⁸ No original substations are known to exist.

The original Hoover Dam substation has been demolished and replaced with a modern switching station. Fieldwork completed in 1994 revealed that the line and towers had been completely removed in one segment between the Bureau of Reclamation boundary near Boulder City and the Eldorado Substation. However, the original towers with retrofitted components are present from the Bureau of Reclamation boundary near Boulder City to Hoover Dam.⁹

Within the Eldorado Valley to Ivanpah Valley section of the original transmission line documented as part of this HAER report, a few of the original towers have been replaced with modern wood towers. Field observations indicate that these towers were erected in 2006. Currently, a series of about twenty modern wood towers support the conductor between Eldorado Substation and the point slightly northwest of the substation where the non-original transmission loop into Eldorado Substation intersects with the original transmission towers and alignment. Between this point and the location of the proposed Ivanpah Substation, original steel towers have been replaced with wood towers; this is out of about 250 total towers within the study area. The line is currently energized at 115kV.

⁶ Johnston, Robert M. 1920. Insulator. U.S. Patent 1,329,770, filed January 11, 1916, and issued February 3, 1920. Johnston, Robert M. 1929. Insulator. U.S. Patent 1,716,963, filed March 26, 1920, and issued June 11, 1929. Also, "Insulator Companies" (website) at <http://www.r-infinity.com/Companies/index.htm#J> (accessed: 2.09.2010).

⁷ Jay K. Sander and Jessica J. Auck. Nevada State Historic Preservation Office, Historic Resource Inventory Form (HRIF) for the "Class III Cultural Resource Inventory for Southern California Edison Eldorado-Ivanpah Transmission Project, San Bernardino County, California and Clark County, Nevada." (Redlands: CA: The Chambers Group, Inc., 2008), 8.

⁸ Email to author from Koral Ahmet (SCE), 7 May 2010. This email also notes that if any original substation buildings were found to exist, no original equipment would exist since the transformers would have been replaced when the line went from 138kV to 115kV.

⁹ Blair, 30.

Minor alterations to original towers include the addition of more modern concrete footings to some towers in areas prone to flooding. Original plan drawings indicate that circular concrete footings were used for some towers as part of the original construction. Though guy wires were a part of the original construction, field observations suggest additional guys may have been added to selected towers to provide additional support in flood or wind prone areas. Most original towers retain their original configuration and insulators. Overall, the line appears to retain a high degree of material integrity within the study area.

HISTORICAL CONTEXT

The United States Congress passed the Boulder Canyon Project Act in 1928, authorizing the construction of Boulder (Hoover Dam) and the All American Canal System. The construction of the Hoover Dam is considered an outstanding achievement in American engineering and the power generated by the dam has been instrumental in the growth and development of Southern California and the American Southwest. A wealth of written information is available on the construction and significance of the Hoover Dam and the electrification of the western states. A comprehensive account of the origins and evolution of the Boulder Canyon Project Act and the resulting Hoover Dam was written by Historian William J. Simonds; an abbreviated version of this account is quoted below.

Location

Hoover Dam and Lake Mead are located in the Black Canyon of the Colorado River about 35 miles southeast of Las Vegas, Nevada. Located on the Arizona-Nevada State line, the dam and reservoir are in the counties of Mohave, in Arizona, and Clark, in Nevada. The Colorado River Basin is an area of over 242,000 square miles that includes parts of California, Nevada, Arizona, Utah, Colorado, New Mexico, and Wyoming. The basin also includes some 2,000 square miles in Mexico.

Investigations

The Bureau of Reclamation began studying construction of dams to control the Colorado River in 1902...Exploratory drilling at potential dam sites began in late 1920 and continued for three years. Detailed topographic surveys were conducted in 1920 and 1921 with geologic surveys being conducted from 1921 to 1923. Also during the period of 1921 to 1923, studies into the availability of materials for concrete aggregates were made and investigations were conducted to determine the locations of railroads and highways for transporting supplies and equipment to construction sites. In 1924, after several years of investigations, the Bureau of Reclamation recommended construction of a high concrete dam at a site in the Black Canyon. The Black Canyon site was chosen for several reasons including accessibility, better foundation material, depth to bedrock, and a greater reservoir capacity. Although the Black Canyon site was chosen, the name Boulder Canyon Project was retained because of prior legislation under that title.

Authorization

The passage of the Boulder Canyon Project Act came after more than two decades of studies and investigations. One of the most difficult steps in gaining approval for the project was determining the equitable allocation of the waters of the Colorado River. The people living in the Colorado River Basin depended on the waters of the river, and in many cases water rights held greater value than land titles. While all of the Basin states recognized the advantages of a large dam on the river, there were

concerns about one state's ability to claim the lion's share of the water, leaving the other state without sufficient water for development. Under the doctrine of prior appropriation which was recognized by all Basin states, an individual or agency meeting certain legal conditions and first appropriating water for beneficial use had first right to the water. Several of the Basin States feared that California, with its vast financial resources and great thirst for water, would be the first state to begin beneficial use of the waters of the Colorado River and therefore claim rights to the majority of the water. It was clear that without some sort of an agreement on the distribution of water, the project could not proceed.

In 1920, representatives of the seven Basin states met and endorsed a proposal for an interstate compact. A commission was formed with a representative from each of the Basin states and one from the Federal Government. The Government's representative was Herbert Hoover, then Secretary of Commerce under President Harding. The commission first met in January 1922 with Hoover presiding. At first, negotiations attempted to establish amounts for each state, but an agreement could not be reached. Hoover proposed that the Colorado River water resources be divided into two groups, the Upper and Lower Basin States, with the division of water within each Basin to be agreed upon at a later date. The Upper Basin consisted of the area above Lees Ferry, Arizona, about 30 miles south of the Arizona/Utah border, with the Lower Basin that area south of Lees Ferry. The proposal, known as the Hoover Compromise, led to the Colorado River Compact, which was signed by the Commissioners on November 24, 1922. The Compact was approved by the legislatures of six Basin States (Arizona did not approve the Compact until 1944) and the Federal Government. The division of water within the Upper and Lower Basins was left to the Basin States.

The first attempt to gain approval for construction of Boulder Dam came in 1922 with the introduction of two bills in the House of Representatives and the Senate. The bills were introduced by Congressman Phil D. Swing and Senator Hiram W. Johnson and were known as the Swing-Johnson bills. The bills failed to come up for a vote and were subsequently reintroduced several times. Many parties joined to oppose the bills. Arizona feared that a thirsty California was trying to get their water. Eastern legislators saw the project as a white elephant that would in no way benefit their constituents. The power lobby, under the guidance of Utah Senator Reed Smoot, saw the project as an attempt by the federal government to get into the power business, directly competing with private industry....In December 1928, after many failures, both the House and the Senate approved the bill and sent it to the President for final approval. On December 21, 1928, President Coolidge signed the bill approving the Boulder Canyon Project.

The Boulder Canyon Project Act authorized construction of a dam in Boulder or Black Canyon, construction of the All-American Canal to connect the Imperial and Coachella Valleys with the Colorado River, and divided the lower basin waters among the lower basin states. In addition, the Act authorized \$165,000,000 for construction and stated the primary purposes of the project as flood control, improvement of navigation on the Colorado River, storage and delivery of water for reclamation and other beneficial uses, and generation of power. The Boulder Canyon Project Act became effective in June 1929 following ratification of the Colorado River Compact by six of the seven states of the Colorado River Basin.

Design

The design of Boulder Dam evolved during several years of study that involved the efforts of some 200 engineers and other workers in Reclamation's design office in Denver and several consulting firms that were retained during the design process...In 1928, the Secretary of Interior appointed a board of engineers and geologists to review all designs and determine the best design from the standpoints of economy, safety, and engineering feasibility. The board, known as the Colorado River Board, approved the lower Black Canyon site and recommended changes to the diversion plan, doubling the diversion capacity to 200,000 [cubic feet per second (cfs)].

By 1928, power development had become an essential feature of the project. Studies into the best arrangement for the power plant and dam led to two designs. The first design placed the power plants and outlet works on the Nevada side of the canyon with two circular vertical shaft spillways on the Arizona side. The second design called for a "U" shaped powerhouse at the base of the dam with spillway tunnels and double banks of outlet works contained in both canyon walls. Intake towers would supply water to the power penstocks and outlet works. Both designs eliminated the outlet conduits through the dam structure and were designed as gravity-arch structures. The second design would form the basis for the final plan...The initial appropriation for construction was made in July 1930.

Construction: Boulder City and Pre-Construction Activities

Before construction of the dam and appurtenant works could begin, an enormous amount of preparatory work had to be undertaken. The site of the dam is a deep canyon more than 30 miles from the nearest town. The site was in the middle of the desert with limited access and no provisions for housing the almost 5,000 people that would work on the project. Before work on the dam itself could begin, many support features had to be constructed. These included transportation and communication facilities, housing, water and sewage systems, power and lighting facilities, and a 150-ton cableway for handling heavy equipment at the dam site.

Since no source of electrical power existed in the vicinity of the dam site, two alternatives were investigated: construction of a diesel or steam powered generating plant near the dam site, or securing power from distant plants already in operation. After examining several proposals, the Government determined that securing power from existing powerplants was the best solution.

The transmission line served two purposes: transmission of power to the dam site during construction, and from the dam to markets in Southern California following completion of the dam. Construction of the line began in December 1930, and was completed in late April 1931. During construction, 1,250,000 pounds of conducting line was used along with 5,000,000 pounds of steel and 49,000 insulator disks. The total cost of the transmission line and substation was approximately \$1,500,000.¹⁰

Boulder Dam-San Bernardino Transmission Line

On October 28, 1930, the U.S. Bureau of Reclamation signed a contract with the Southern Sierras Power Company and the Nevada-California Power Company for the construction of

¹⁰ Wm. Joe Simonds. "The Boulder Canyon Project: Hoover Dam." Electronic Document. http://nevada-history.org/boulder_project_by_simonds.html (accessed 19 March 2010).

a 225 mile-long power transmission line from a steam-powered generating station at San Bernardino, CA to the dam site. The contract also included the construction of a substation near the dam, on the Nevada side of the river. Built in 1930-31, the transmission line provided both the electrical energy required for the construction of the dam and domestic service to Boulder City. After the dam was completed, power transmission on the line was reversed to provide electricity from the dam to markets in Southern California. Construction of the line began in December 1930, and power was available for the dam construction project on June 25, 1931.¹¹

As part of the contract, eight months were allotted for the construction of the transmission line and Boulder Substation. Three days after the contract was signed, survey parties were in the field for location work and construction activities began within six weeks. The line crews worked at a record-setting pace, completing the 225-mile long (132,000-volt) line from San Bernardino to the dam site in only 225 days, despite having to navigate some of the most rugged and inhospitable terrain in the country. Power delivery across the new line to the Boulder Substation, located on the rim of the canyon roughly 700 feet from the Nevada abutment of the Dam, began on June 25, 1931. During the next six years, over 100 million kilowatt-hours were sold to the dam construction project.¹² An article in *Compressed Air Magazine* (1931-35) further describes the construction of the transmission line:

Despite the fact that a considerable portion of the route was across mountainous country, the [transmission line] was put in place at the rate of 1.45 miles a day, which is said to constitute a record for such work. Field camps for from 50 to 80 men each were established at suitable intervals, and as many as five of them were maintained at a time. In some cases the trucks that delivered materials and supplies had to make their own roads; and on one occasion it was necessary to let a truck down a steep grade by means of a winch and cable. Construction activities extended over a distance of 125 miles at one time.

Construction of the substation on a high rocky point having a steep approach was accompanied by difficulties. A compressor to furnish air for excavating the 2,100 cubic yards of rock required to be moved for the placing of foundations was packed up the hillside in sections by burros. Later a temporary switchback road, having grades up to 17 per cent, was built to permit the moving in of construction materials and station equipment. Power was turned on June 25 [1931], beating by several days the time limit of 240 days allowed for designing and building the system. R.H. Halpenny was in charge of design and E. J. Waugh was construction engineer. Field forces on line construction were in charge of C. H. Rhudy; and H. O. Watts supervised the building of the substation. The line is insulated for 132,000 volts, but power is being transmitted at 80,000 volts. A 6.83-mile, 33,000-volt, wood pole line was built from the substation to Boulder City, and a .73-mile, 2,300-volt line was

¹¹ Lynda Blair, "An Evaluation of Eighteen Historic Transmission Line Systems that Originate From Hoover Dam, Clark County, Nevada," p.29. Harry Reid Center for Environmental Studies, University of Nevada – Las Vegas, April 1994. Also, Simonds. "The Boulder Canyon Project: Hoover Dam."

¹² William A. Myers, *Iron Men and Copper Wires: A Centennial History of the Southern California Edison Company*, (Glendale, CA: Trans-Anglo Books, 1983), 184-187; quoted in Hatheway, Roger, State of California, Department of Parks and Recreation, 523 Series Forms: *Edison Company Boulder Dam-San Bernardino Electrical Transmission Line*. Prepared by (Hatheway & Associates, August 2006), 9.

constructed into the canyon to furnish power to the No. 1 pumping station of the water supply system for Boulder City.¹³

Commercial power production in the Hoover Dam power plant began on October 26, 1936. By August 1937, commercial power distribution began on the Southern Sierras Power Company line, two years in advance of the scheduled delivery date of 1940. Energy was delivered into the Electric Corporation's system at San Bernardino over the line completed in 1930-31.¹⁴ (Note: Prior to 1936, the Nevada-California Electric Corporation, a holding company, owned the Nevada-California Power Company and the Southern Sierras Power Company. In 1936, the holding company became the operating company, and the name was changed to the California Electric Power Company in 1941. The Southern California Edison Company acquired California Electric on January 1, 1964.)¹⁵

PART II. STRUCTURAL/DESIGN INFORMATION

The section of transmission line documented in this HAER report extends between the location of the proposed Ivanpah Substation in Ivanpah Valley, San Bernardino County, California and Eldorado Substation located approximately 35 miles northeast in Eldorado Valley, Clark County, Nevada. Located primarily on Bureau of Land Management (BLM) land, the line traverses the low-lying area of Ivanpah (dry) Lake before it crosses Interstate 15 at Primm, Nevada. From there it travels northeast, crossing McCullough Pass and continuing northwest to Eldorado Substation. With the exception of the towers located at Primm, the line travels along a corridor with other electrical transmission lines across what is largely undeveloped and rugged desert terrain. An unpaved access road runs the full length of the line.

Five main tower types were used for the construction of the entire line and all five types are represented within this 35-mile section.¹⁶ The tower types are described below, beginning with the most common tower type. Original drawings indicate there were different base types ("FEH", "FCH", "FEHH", "FCHH", etc.) but their exact purposes are unknown.¹⁷ Also unknown is which towers were originally set with concrete footings; most were constructed without concrete footings.

Type "H" Standard Tower (H-Frame)

This standard tower type is used to support both suspension and dead-end stringing methods (primarily suspension) and is the most common tower type found on the line. The Type "H" tower stands 52' tall and has two steel lattice legs spaced 17' apart at center. Each leg measures 2' square and the top cross-arm that ties the vertical masts together measures

¹³ "The Story of the Hoover Dam," *Compressed Air Magazine*, 1931-35 (series of articles republished in 2009 by Nevada Publications, Las Vegas, NV), 33-34.

¹⁴ William A. Myers, *Iron Men and Copper Wires*, 184-187; quoted in State of California Department of Parks and Recreation, 523 Series Forms: *Edison Company Boulder Dam-San Bernardino Electrical Transmission Line*. Prepared by (Hatheway & Associates, August 2006), 9.

¹⁵ Lynda Blair, "An Evaluation of Eighteen Historic Transmission Line Systems that Originate From Hoover Dam, Clark County, Nevada," p.29. Harry Reid Center for Environmental Studies, University of Nevada – Las Vegas, April 1994.

¹⁶ Original drawings suggest that two additional tower types ("AH" and "AHS") were also constructed. However, no information was found that described the configuration of these tower types and no examples are represented on this line section.

¹⁷ It is assumed, but not substantiated, that the different base types were used to accommodate varying terrain requirements.

34' long and 2' wide at the widest point. Suspension tower insulator strings attaching each the three conductors to the tower have nine individual porcelain insulation units; dead-end towers have ten. At least one tower in each mile of standard construction was guyed; however, others appear to have been guyed at a later date in lake areas and others areas prone to flooding or wind-loading.

Type "AL" Tower (A-Frame)

This type of structure is used for line angles between 25-50 degrees. The Type "AL" tower stands 55' tall, not including the footings, which are buried at a depth of 8' below grade. The total length of the upper cross-arm is 32'. While most cross arms are placed symmetrically atop the base structure, some are offset to increase the clearance of conductor jumpers from tower components. Tower legs are spaced about 17' apart on front/back and 15' apart on sides. These towers are all configured as dead-end structures with insulator strings comprised of 10 individual porcelain insulation units. These towers are self-supporting (no guy wires).

Type "T" Transposition Tower (Transposition)

The method of transposing the three conductors on this line was developed to meet the particular conditions encountered. The line followed the same general route as the transcontinental line of the Southern California Telephone Company, and this design was developed to prevent inductive disturbances on the telephone circuits.¹⁸ The design of these towers attracted attention at the time because transposition was accomplished with a single tower, rather than with two towers, as had been common practice.¹⁹

The Type "T" towers are comprised of lattice steel masts connected at the top by a cross-arm of the same configuration. They stand 64' tall, with legs and a cross-arm that are 2' square. These towers in suspension configuration have 9 unit insulator strings (2 strings total) and 10 unit insulator strings in dead-end configuration (6 strings total). These towers are always guyed.

Type "SW" Tower - Sectionalizing Switch Tower (Switch tower)

The line was provided with switches for opening the line at six points in the 225 miles of length.²⁰ The Type "SW" Tower stands 54' tall, not including the footings, which are buried at a depth of 9' below grade. The total length of the upper cross-arm is 34'. Legs are spaced about 17' apart on front/back and 15' apart on sides. These towers are self-supporting (no guy wires) and similar to Type "AL" Tower (A-frame) in configuration except the cross-arm on top of the base structure is inverted to support dead-end and switching functions. Standard 10 unit standard dead-end insulator strings are configured with unique 4 unit vertical insulators.

Type "AP" Tower - Angle Structure (Three-legged Angle Tower)

This structure is used for line angles of 50 to 90 degrees.²¹ No original plan drawings are available for this tower type, however the structure is similar to that of Type "T" towers, but with three legs instead of two. These towers are always guyed.

¹⁸ "Nevada-California Electric Corporation – Hoover Dam Line Construction, 1930-31," (documentary album). Southern California Edison Collection (Collection 13, Volume 152), Huntington Library, San Marino, CA.

¹⁹ Dames & Moore, 118. Also, Southern Sierras Power Company drawing No. 633-103 (27 December 1930), "Special Clevis & Yoke," drawing provided by Koral Ahmet from SCE archives.

²⁰ "Nevada-California Electric Corporation – Hoover Dam Line Construction, 1930-31," (documentary album).

²¹ Ibid.

Of the almost 260 towers documented as part of this 35-mile section of transmission line, about 200 are Type "H" standard suspension towers and six are Type "H" standard dead-end towers. There are thirteen Type "AL" towers, six Type "T" towers and one Type "AP" tower. As a whole, this section of transmission line and all appurtenant features appear to be in good condition and only a few towers have been replaced with modern wood towers; most of the tower replacement has occurred in the area of Eldorado Substation.

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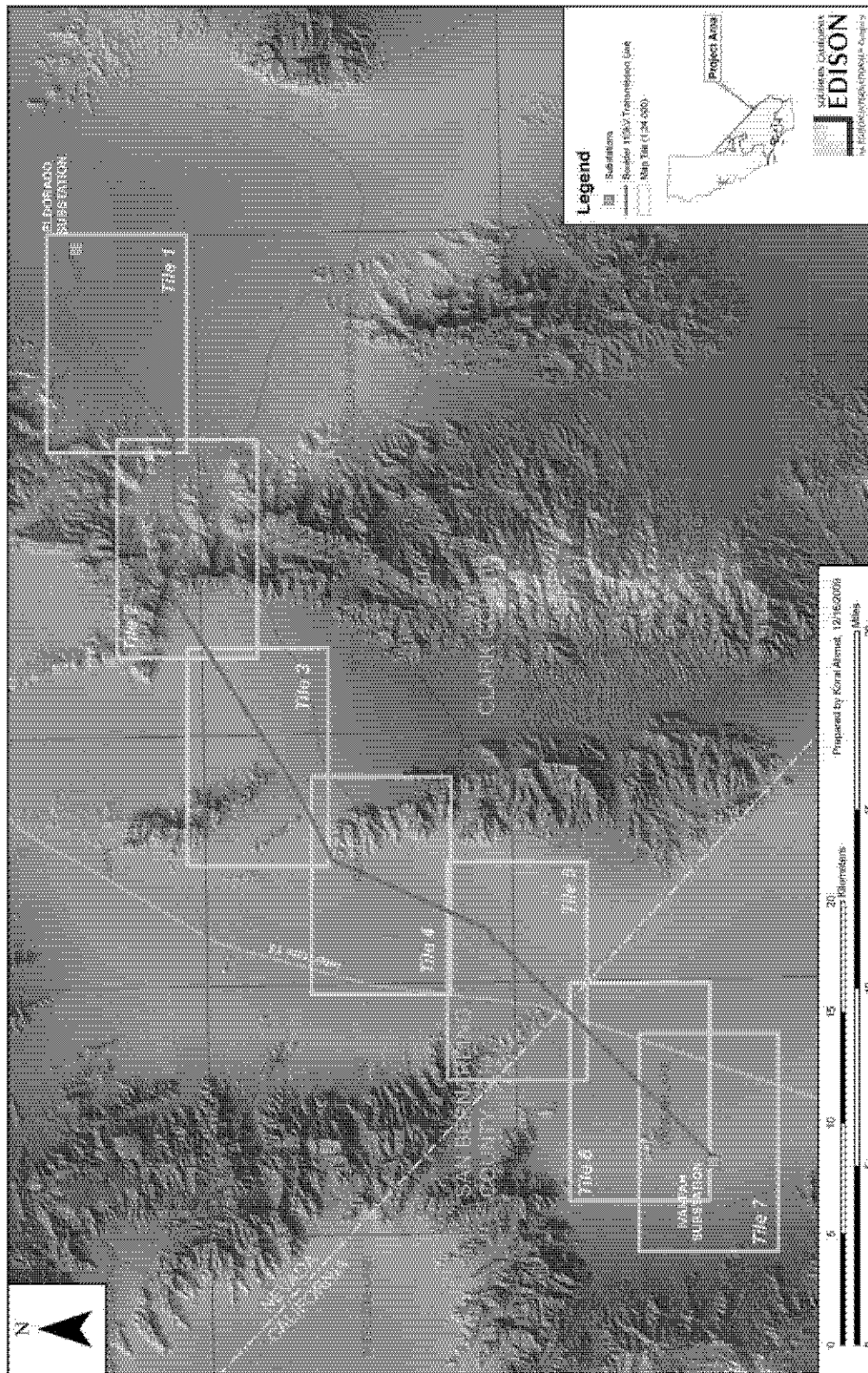
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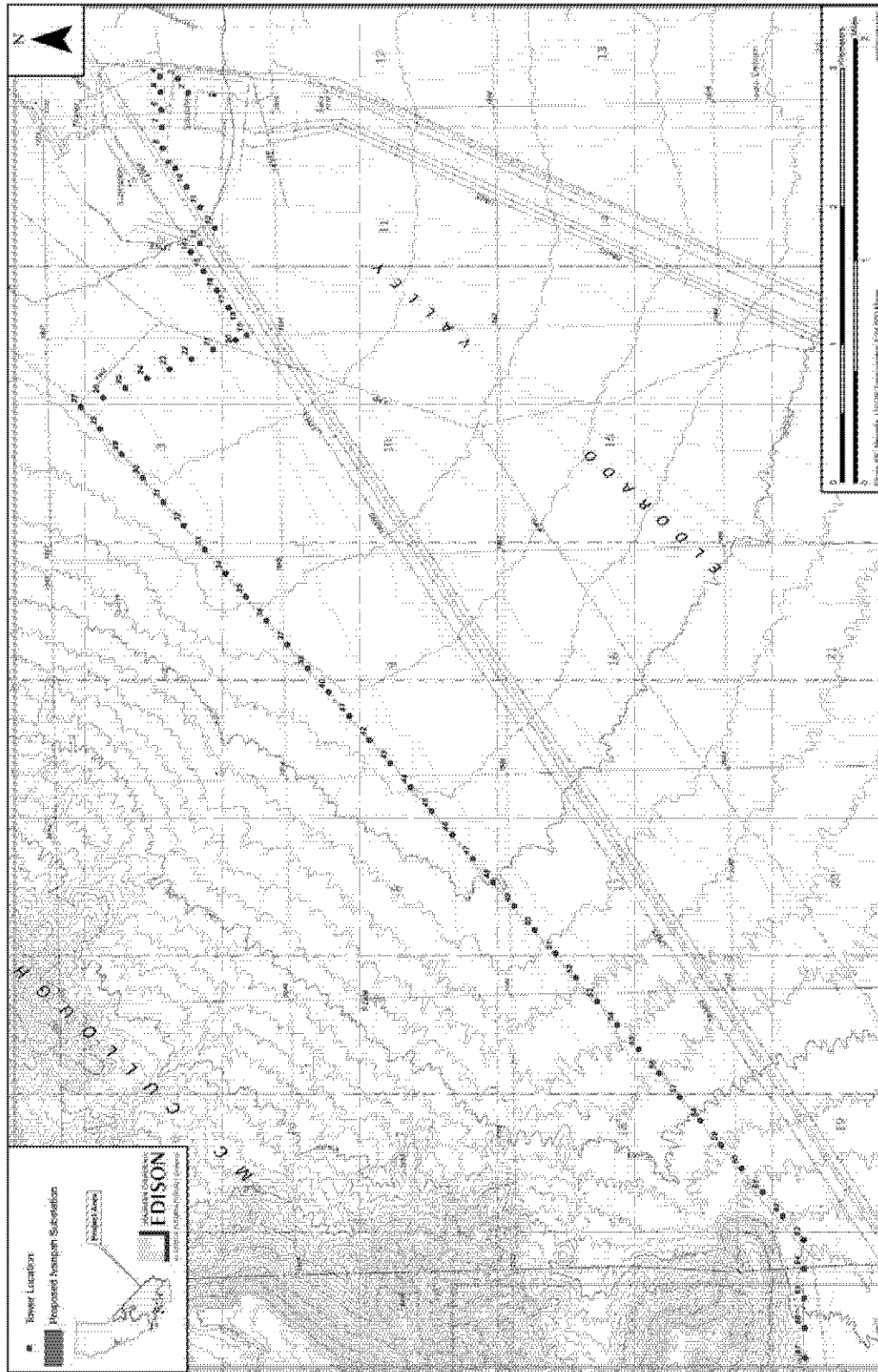
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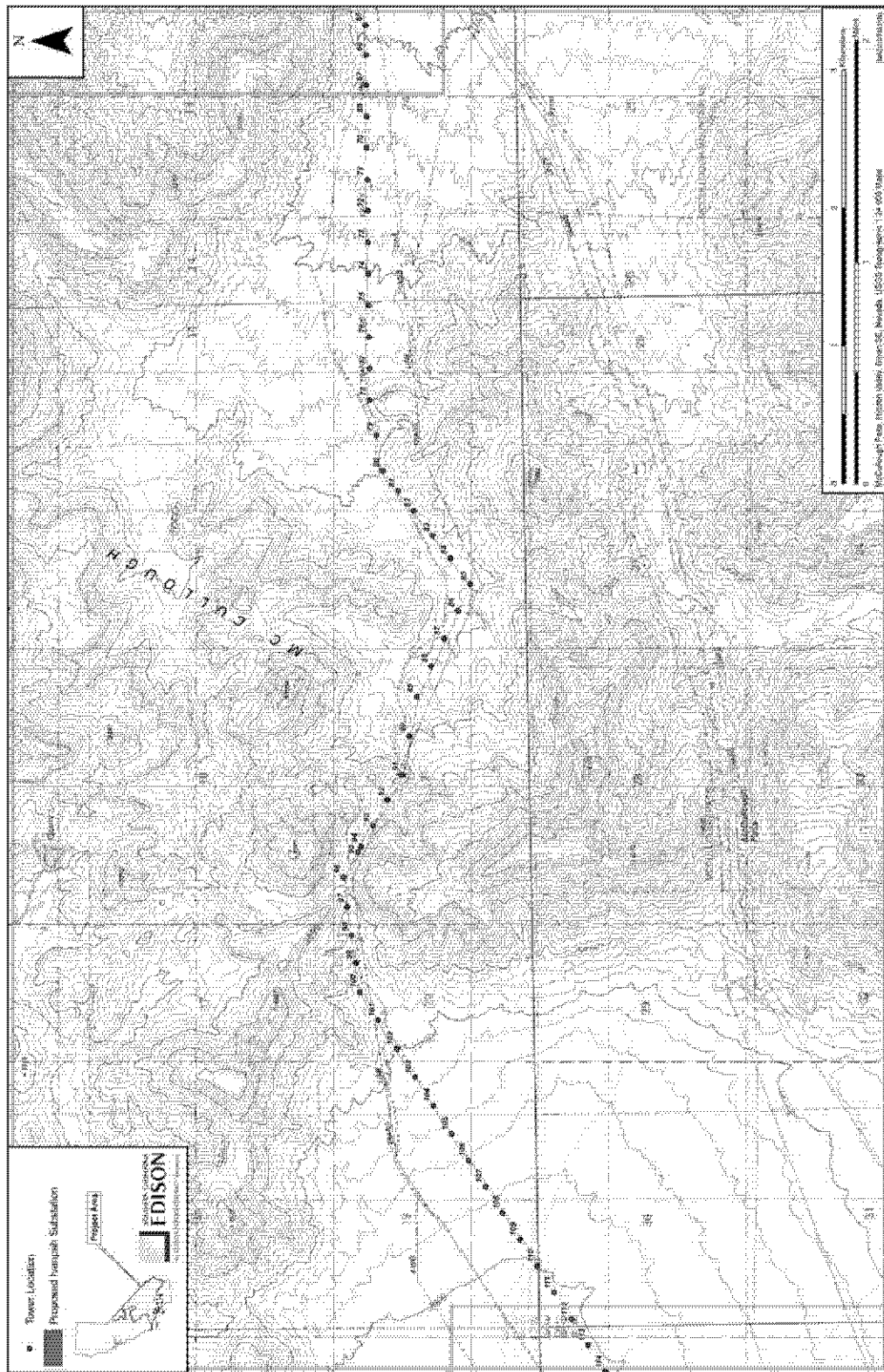
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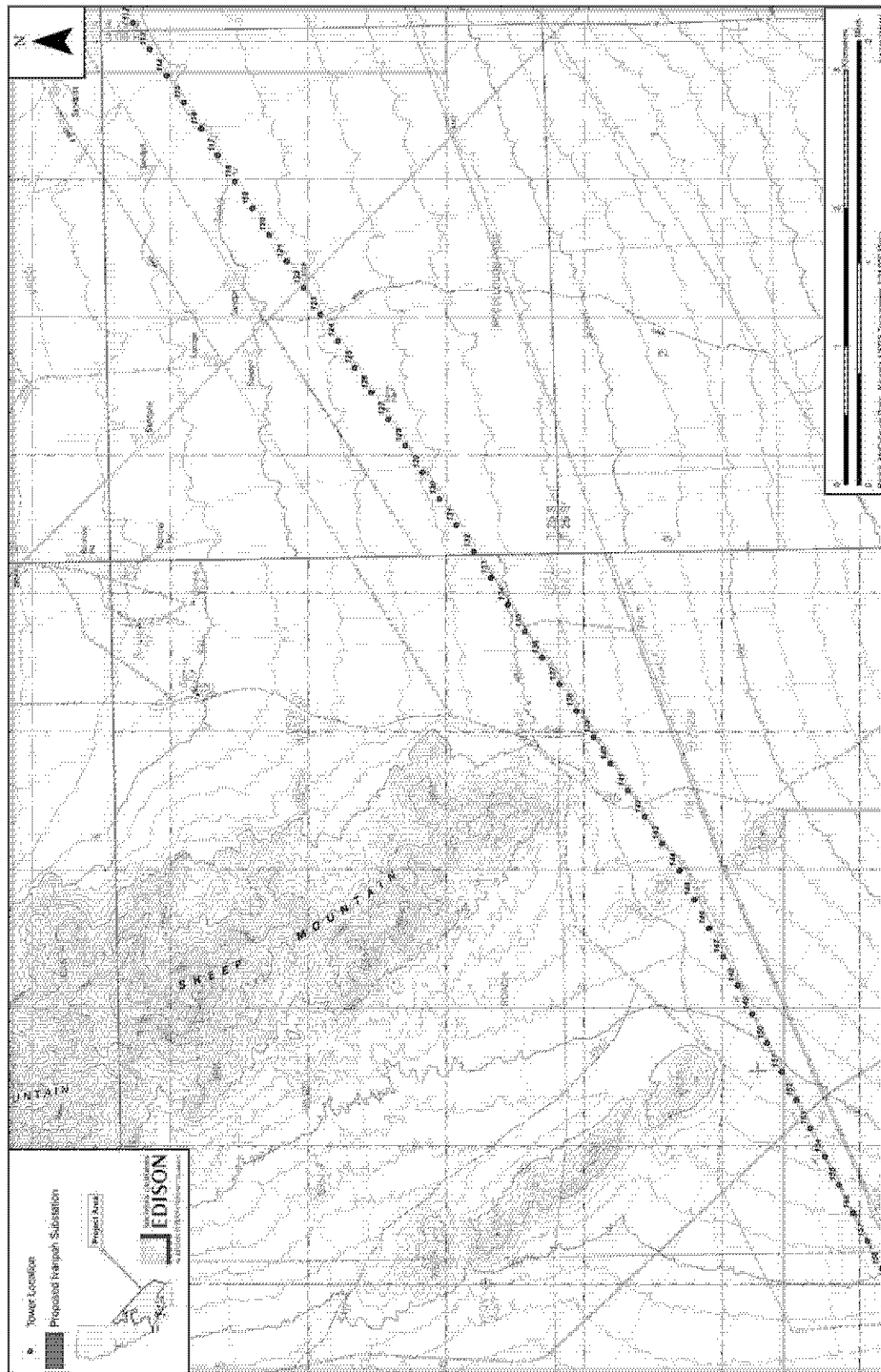


Line Maps: Tile 1

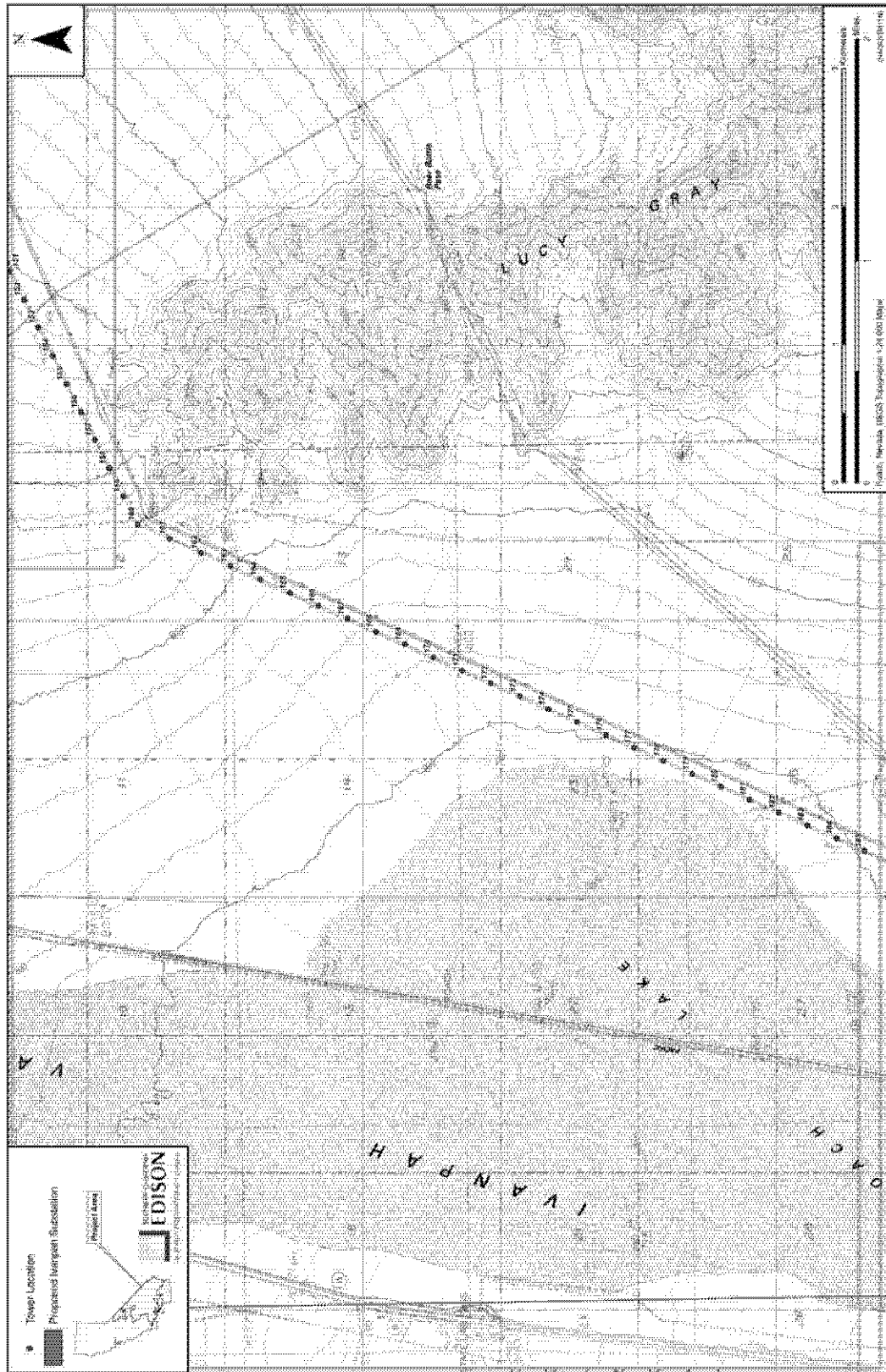


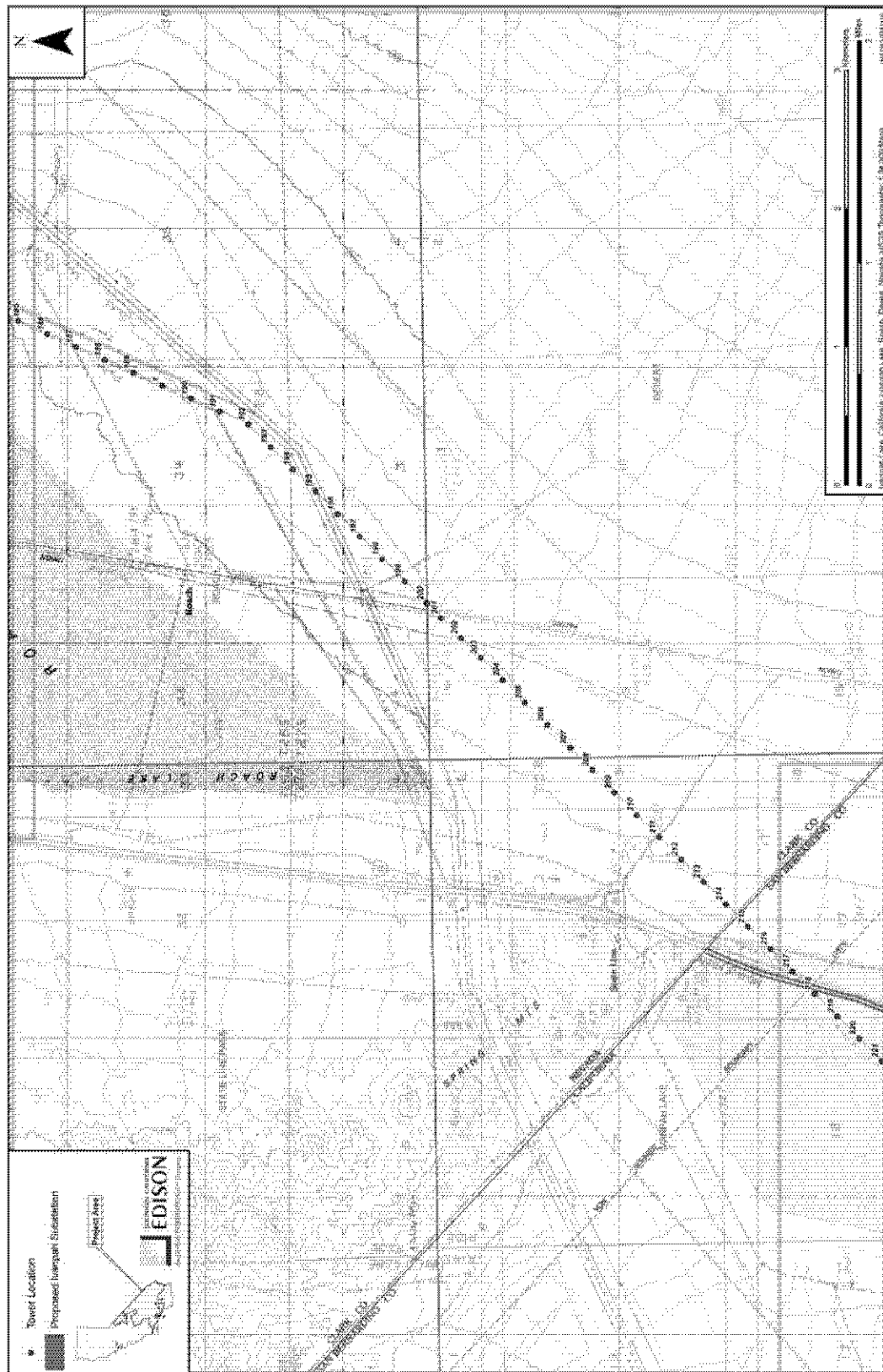
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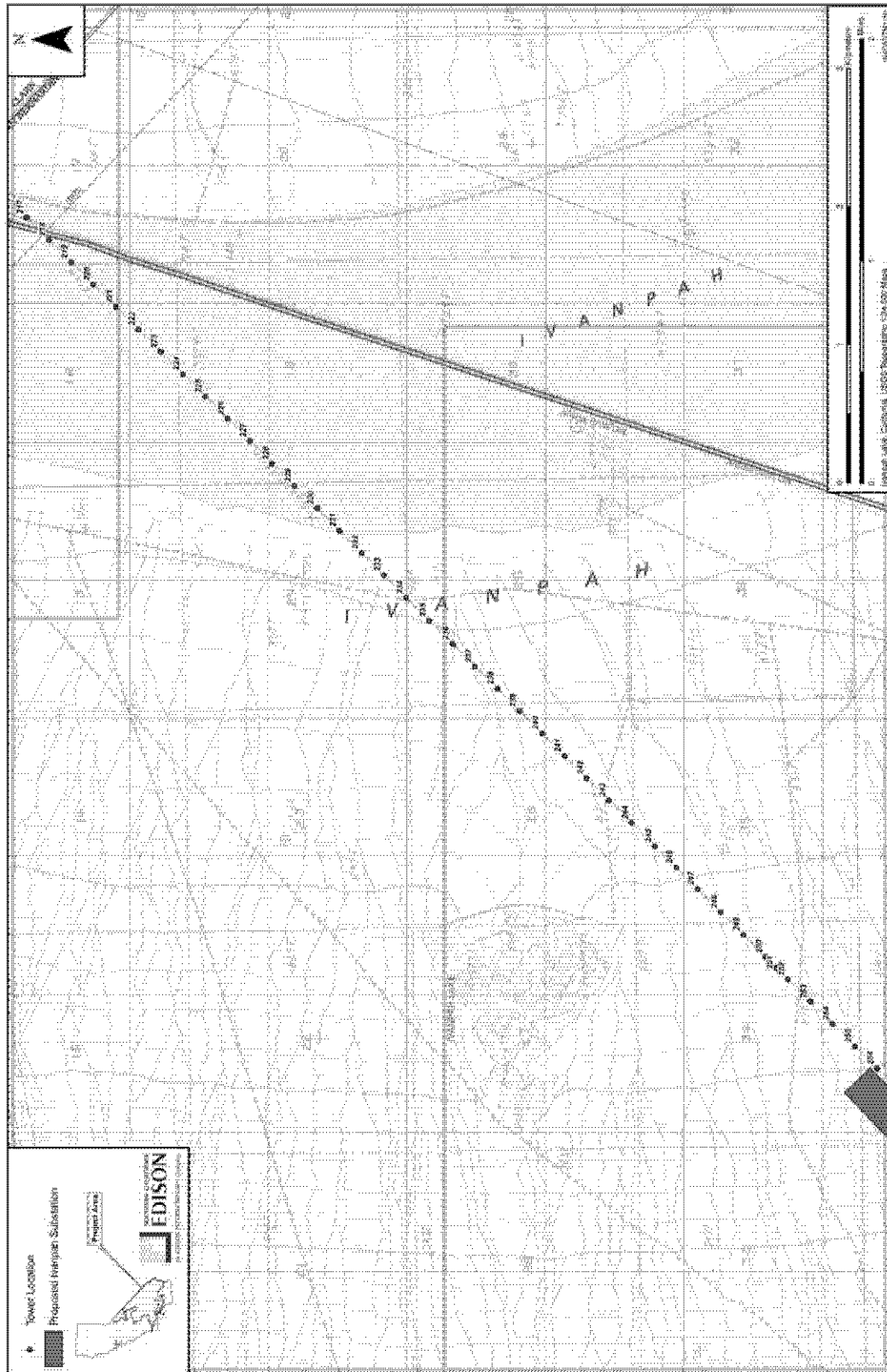


Line Maps: Tile 4





Line Maps: Tile 6



Line Maps: Tile 7

